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Studies on the zeolites. Part IV. Ashcroftine (kalithomsonite of S. G. Gordon).[1]

By Max H. Hey, B.A., B.Sc., and F. A. Bannister, M.A.
Assistant-Keepers in the Mineral Department of the British Museum of Natural History.

[Read November 1, 1932.]

In 1924 S. G. Gordon[2] described as a variety of thomsonite a pink zeolitic mineral occurring as a fine crystalline powder in cavities of augite-syenite at Narsarsuk, Greenland. The material was described as orthorhombic, with two good cleavages $a(100)$ and $b(010)$ and a less perfect one $c(001)$; no other faces were observed on the minute prismatic crystals. The refractive indices Gordon measured as α 1·535, β 1·537, γ 1·545, with the optic orientation $a = b$, $\beta = a$, $\gamma = c$, and optic sign positive. Analysis gave the figures under I (p. 307), and as these agree with the composition to be expected for a potassiferous thomsonite, apart from the high water content, Gordon regarded it as such, and gave it the varietal name kalithomsonite.

As will be seen from the figures under II (p. 307), the atomic ratios, per 80 oxygen atoms, do indeed suggest the thomsonite unit-cell formula $Na_{4+n}Ca_{8-n}Al_{20-n}Si_{20+n}O_{80}.24H_2O$, apart from the high water content; but the study of thomsonite by one of the

[1] Part III. Natrolite and metanatrolite. Min. Mag., 1932, vol. 23, p. 243.
[2] S. G. Gordon (J. E. Whitfield, analyst), Proc. Acad. Nat. Sci., Philadelphia, 1924, vol. 76, p. 261. [Min. Abstr., vol. 2, p. 385.]

authors[1] had shown that artificial potassiferous thomsonites (produced by base-exchange reactions) only show a very small increase in refractive index over non-potassiferous material of the same Si/Al-ratio, and there is no tendency whatever to an increase of β and α, relatively to γ, which could lead to the changed optic orientation of Gordon's material. It therefore seemed very doubtful whether the substance really was a thomsonite at all.

Fortunately, a portion of the original material presented by Mr. Gordon to the British Museum in 1924 (B.M. 1924, 867), was available for examination. In view of J. E. Whitfield's analysis, a new chemical examination seemed superfluous, but one of us (F. A. B.) undertook an X-ray study of selected fibres, which had been found to show agreement with Gordon's optical data. Gordon's data were in general confirmed, except that no difference in facility of the two best cleavages (*a* and *b*) could be noticed, nor any difference in the refractive indices for vibrations perpendicular to these cleavages. The fibres are too thin for examination along their length, but observations on fibres lying on *a*(100) or *b*(010), with a high-aperture oil-immersion system, supported the idea that they may be uniaxial; certainly 2V cannot exceed 36°.

This conclusion was fully substantiated by the X-ray work, Lauegrams along the *c*-axis clearly showing that the symmetry is tetragonal, the principal axis being Gordon's *c*-axis, parallel to the elongation of the fibres. The unit cell is remarkably large, the dimensions being *c* 17·49, *a* 34·04 Å., both $\pm$0·05, giving an axial ratio *c*/*a* of 0·514. The rotation photographs are, in consequence, too complex to be completely indexed, but it could be observed that (*h*0*l*) is halved for (*h*+*l*) odd; assuming holohedral symmetry this would lead to the space-group D_{4h}^{14}, but the evidence is insufficient to decide definitely.

The specific gravity was determined as 2·61, the accuracy not being very great (about $\pm$0·05) on account of the small size of the crystals. From this figure, Whitfield's analysis, and the measured cell-size, the atomic cell-contents given under III are calculated. The figures are so large that it is difficult to assign a definite unit-cell formula, but assuming that the minimum number of similar positions in the unit cell is four, they may be regarded as an approximation to

$$Na_{40}K_{40}(Ca,Mg,Mn)_{40}Al_{160}Si_{200}O_{720}.320H_2O, \text{ or}$$
$$40[NaK(Ca,Mg,Mn)Al_4Si_5O_{18}.8H_2O],$$

[1] M. H. Hey, Min. Mag., 1932, vol. 23, p. 51.

by far the most complicated unit-cell formula yet found among inorganic compounds.

Ashcroftine ('kalithomsonite'), analysis by J. E. Whitfield:

	SiO_2.	Al_2O_3.	CaO.	MgO.	MnO.	Na_2O.	K_2O.	H_2O+.	H_2O-.	Total.	O %.
I.	38·09	26·61	5·72	0·87	0·79	3·62	5·65	12·00	6·40	99·75	36·97

Atoms per 80 atoms oxygen:

	Si.	Al.	Ca.	Mg.	Mn.	Na.	K.	H_2O.	Si+Al.	Ca+Na+K.
II.	22·01	18·13	3·54	0·75	0·39	4·06	4·16	35·46	40·14	12·90

Atoms per unit cell:

	Si.	Al.	Ca.	Mg.	Mn.	Na.	K.	H_2O.	O.	H_2O+.
III.	203·2	167·4	32·8	6·9	3·6	37·5	38·6	328·4	740·8	214·2

'Kalithomsonite' is, therefore, not a variety of thomsonite, but an independent species. Now names formed on the principle of kalithomsonite have been in use for some time for artificial base-exchange products prepared from the zeolites (e.g. silver-natrolite, ammonium-stilbite), for natural zeolites of abnormal composition (e.g. barium heulandite), and for end-members (actual or hypothetical) of isomorphous series (e.g. calciothomsonite, Natronthomsonit).[1] All these uses seem quite legitimate, and in each case the names cover varieties and not species.[2] It therefore seems undesirable to retain the name kalithomsonite for a mineral which is not simply related to thomsonite; such a name belongs properly to the artificial potassiferous thomsonites prepared by one of the authors.[3]

It is therefore proposed to replace the name kalithomsonite, for the material above described, by *Ashcroftine*, in honour of Mr. Frederick Noel Ashcroft, whose munificent gifts of zeolites to the British Museum have greatly enriched the collections and enabled this series of studies to be undertaken.

Ashcroftine, then, is a tetragonal mineral, with a unit cell measuring c 17·49, a 34·04 Å., and containing approximately

$$40[NaK(Ca,Mg,Mn)Al_4Si_5O_{18}.8H_2O].$$

Its refractive indices are ϵ 1·545, ω 1·536, and it occurs as small needles bounded by the cleavage forms $a(100)$, $c(001)$. Specific gravity $2·61 \pm 0·05$.

[1] For other examples of all three uses, see the lists of new mineral names collected by Dr. L. J. Spencer, Min. Mag., vols. 11–22.

[2] Even Kali-Harmotom (= phillipsite) of L. Gmelin, 1825, belongs to the same isomorphous group as harmotome.

[3] M. H. Hey, Min. Mag., 1932, vol. 23, pp. 109–110.

The amount of material available was not sufficient to undertake vapour-pressure and base-exchange work. Experiments with a small quantity of material showed no appreciable change in optic properties after digestion in boiling NaCl solution for 700 hours, or fusion with $NaClO_3$ at 250° C. for 48 hours, followed by soaking with water, but it is not certain that any appreciable base-exchange was obtained. Whitfield's figure for H_2O- shows that the water is not very firmly held.

On stichtite from Cunningsburgh, Shetland Islands.

By H. H. Read, D.Sc.
Professor of Geology, University of Liverpool,
and B. E. Dixon, M.Sc., A.I.C.
H.M. Geological Survey Laboratory.

[Read November 1, 1932.]

THE rare mineral stichtite, a complex hydroxy-carbonate of magnesium, chromium, and iron, was defined in 1910 by W. F. Petterd [1] on material from the Adelaide silver-lead mine, Dundas, Tasmania. Petterd's description, together with detailed optical and chemical studies by A. S. Wesley, L. K. Ward, L. Hezner,[2] and A. Himmelbauer,[3] were collected by W. H. Twelvetrees [4] and issued by the Tasmanian Department of Mines in 1914. A new analysis of the Tasmanian material is included by W. F. Foshag [5] in his investigation of the hydrotalcite group.

The mineral was next recorded by E. Poitevin and R. P. D. Graham [6] from the Megantic mine, Black Lake area, Quebec; no chemical data of this occurrence are available.

The third occurrence of stichtite, in the Barberton district, Transvaal, was first mentioned by E. J. Dunn [7] in 1918, and described in detail by A. L. Hall [8] in 1922. The latter gave chemical analyses of the stichtite and of the rock in which it is found.

[1] W. F. Petterd, Catalogue of the minerals of Tasmania, 1910, pp. 167–169.

[2] L. Hezner, Centr. Min., 1912, p. 569.

[3] A. Himmelbauer, Min. Petr. Mitt. (Tschermak), 1913, vol. 32, p. 135.

[4] W. H. Twelvetrees, Tasmania Dept. Mines, Geol. Surv. Record, 1914, no. 2.

[5] W. F. Foshag, Proc. U.S. Nat. Museum, 1920, vol. 58, p. 147. [Min. Abstr., vol. 1, p. 175.]

[6] E. Poitevin and R. P. D. Graham, Canada Dept. Mines, Geol. Surv., Mus. Bull., 1918, no. 27, pp. 27–30. [M.A. **1**–9.]

[7] E. J. Dunn, Industrial Australian and Mining Standard, 1918, vol. 60, p. 775. [M.A. **1**–47.] The mineral had been found by Dunn in 1883, long before the discovery of the Tasmanian stichtite, and in 1885 he presented a specimen to the British Museum collection of minerals, which at the time was doubtfully referred to kämmererite.

[8] A. L. Hall, Trans. Geol. Soc. S. Africa, 1922, vol. 24 (for 1921), p. 182. [M.A. **1**–339.]

At the three localities of stichtite hitherto described, the mode of occurrence of the mineral is the same, the stichtite forming small patches, veinlets, or coatings to slip-planes, in chromite-bearing serpentine.

The Shetland stichtite that forms the subject of this note was found by H. H. Read whilst a member of H.M. Geological Survey. He desires to express his thanks to Sir John Flett, F.R.S., Director of the Survey, for permission to investigate the material after he had left that service, and especially for the facilities afforded of chemical co-operation with B. E. Dixon.

The locality of the Shetland occurrence is 665 yards E. 14° S. of the 800-foot triangulation point on the top of Hoo Field, Cunningsburgh, Mainland. The surrounding country has been mapped by J. Knox for the Geological Survey.[1] The sedimentary metamorphic rocks of the district consist of a varied series of dominantly argillaceous rocks, including chloritoid-schists, together with limestones, calc-silicate-rocks, black amphibole-rocks and graphitic schists. In this series occur large masses of serpentine and talc-schist, bounded by planes of shear. The stichtite is found in one of these serpentine masses.

The serpentine typical of the mass is a compact greenish rock, in thin slice seen to be composed almost entirely of small blades of colourless antigorite, similar in optical properties to the antigorite associated with the stichtite and described below. The blades are often arranged in two sets, producing a lattice effect, but in some slices no arrangement is discernible. In addition to the antigorite, there are present a few grains of brown chromite, and still fewer tiny specks of black iron oxide.

In such a greenish serpentine the stichtite is conspicuous as rose-pink patches, usually rather rounded in form, at times somewhat elongated and rarely stripe-like. The maximum size of the mineral aggregates is half a centimetre. Slices show that the associates of the stichtite are antigorite, chromite, iron oxide, and dolomite.

The stichtite occurs as fibres or matted masses of fibres, variable in thickness, and often curved or with noded ends. These fibres are perpendicular to irregular kernels of residual chromite (fig. 1). There can be no doubt that the stichtite aggregates have the shapes of original chromite grains. The specific gravity of the stichtite is 2·19 at 17° C.

[1] Summ. Prog. Geol. Surv. Great Britain for 1930, 1931, part 1, p. 73.

Under the microscope the stichtite fibres are delicate rose-pink in colour and show no pleochroism. They have straight extinction and positive elongation; no interference-figures were obtained. The determination of the refractive indices of these fine and often bent fibres is not altogether satisfactory. The immersion method was employed. The maximum refractive index is for light vibrating

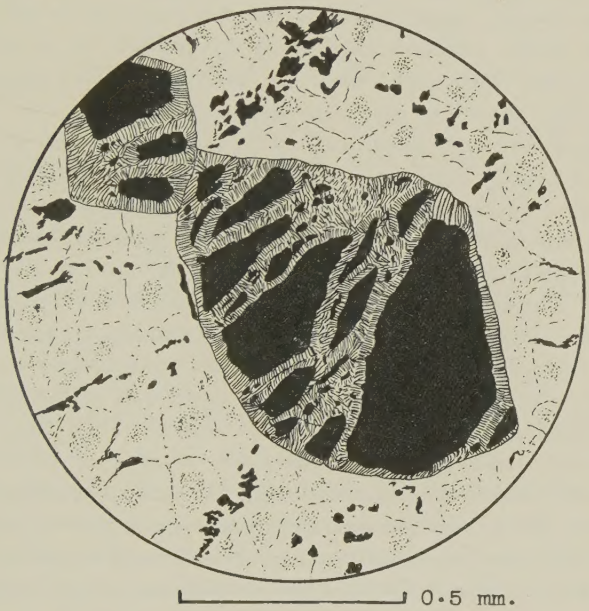

Fig. 1. Stichtite replacing chromite in antigorite-serpentine from Cunningsburgh, Shetland. ×60.

parallel with the fibres. Concordant and quite satisfactory observations gave 1·559 for sodium-light at 17° C. Determination of the values for light vibrating across the fibres is not so good; the difficulty of working with bunches of fine curving fibres in this position vitiates the results. The best observations gave 1·543 for sodium-light at 17° C.; probably the lowest refractive index is slightly lower than this. It seems possible that the refractive index for rays vibrating across the fibres is not constant, i.e. the mineral is not uniaxial.

Of the associates of the stichtite, the antigorite occurs as criss-crossing blades, with positive elongation; α across the blades is

1·564 (not a good reading), γ along the blades is 1·572, both for sodium-light at 18° C. The mineral is negative, with an optic axial angle of moderate size; the optic axial plane lies parallel to the elongation and perpendicular to the plane of the blades. Chromite is brown in very thin sections; it forms irregular fragments surrounded by radiating fibres of stichtite. Black iron oxide occurs as small grains, often in strings, or occasionally as thin irregular veinlets. Dolomite, determined by the refractive index of cleavage rhombs, builds small patches or thin veinlets. It is, of course, possible that other carbonates, e.g. magnesite, are present in this association. In view of the procedure adopted in the chemical analysis of the partly purified stichtite, mounts in oils of the material analysed, aggregating in all perhaps half a gram, were searched for carbonate; no more than half a dozen grains were found, so that even if carbonates other than dolomite are present, they can affect the interpretation of the chemical analysis only to a negligible degree. The veinlets of iron oxide or of dolomite never penetrate the stichtite-chromite areas, though they may run along their margins.

The material, mechanically purified as far as possible, was subjected to a complete analysis. It was fused with sodium carbonate and potassium nitrate in a platinum crucible until the melt had completely dissolved. A considerable amount of platinum was dissolved in this way, and also during the subsequent separation of the silica, but in view of the importance of a complete solution of the chromite and of an accurate determination of the silica, this was unavoidable. The platinum, which would have proved troublesome later, was separated from the solution by means of hydrogen sulphide after the removal of silica by evaporation to dryness and filtration.[1] The iron, aluminium, and chromium were separated by a double precipitation with ammonia and determined titrimetrically and gravimetrically. In the filtrate manganese, calcium, and magnesium were estimated by usual methods. No titanium, phosphate, nickel, cobalt, or non-chromitic ferrous iron were detected. The ferric iron, chromium, and magnesium of the stichtite were determined in a solution obtained by extracting the sample with cold N–H_2SO_4. The total water was estimated by Penfield's method, and carbon dioxide by absorption in caustic potash; these results were corroborated by the loss on ignition (20·95 %). The complete analysis is shown under 1.

[1] B. E. Dixon, Journ. Chem. Soc., 1931, p. 2311.

	1.	2.	3.	4.	5.	6.	7.
SiO_2 ...	8·51	—	—	—	3·87	2·09	4·50
Al_2O_3 ...	1·10	—	—	—	—	2·24	0·90
Cr_2O_3 ...	27·10	17·75	17·75	11·5	20·44	14·08	8·90
Fe_2O_3 ...	6·52	3·50	3·73	9·0	—	4·04	10·60
FeO ...	8·95	—	—	—	1·10	0·28	0·85
MnO ...	0·05	—	—	—	—	—	—
MgO ...	26·72	39·49	39·55	36·0	37·12	36·59	36·70
CaO ...	0·10	—	—	—	—	trace	—
CO_2 ...	3·14	6·83	6·17	7·2	10·45	6·94	6·90
H_2O+ ...	17·46	32·43	32·80	36·1	26·31	33·01	26·80
H_2O- ...	0·24				0·95		3·65
	99·89	100·00	100·00	99·8	100·24	99·27	99·80

1. Impure stichtite from Cunningsburgh, Shetland. Analyst, B. E. Dixon. $H_2O \pm 105°$ C.
2. Analysis 1 recalculated after deducting impurities.
3. Calculated percentage composition corresponding to the formula $(Cr, Fe)_2O_3.7MgO.CO_2.13H_2O$, with $Cr_2O_3 : Fe_2O_3 = 5 : 1$.
4. Stichtite from Dundas, Tasmania. W. F. Petterd, 1910. Analyst, A. S. Wesley.
5. Ditto. L. Hezner, 1912. $H_2O \pm 120°$ C.
6. Ditto. W. F. Foshag, 1920.
7. Stichtite from Barberton, Transvaal. A. L. Hall, 1922. Analysts, J. McCrae and H. G. Weall. Also NiO 0·10, Na_2O 0·05, K_2O trace. $H_2O \pm 100°$ C.

For the determination of the mineral composition of the sample analysed, the acid-soluble Fe_2O_3, Cr_2O_3, and MgO (1·61, 8·16, and 18·05 %, respectively) were calculated to stichtite, and the SiO_2 to serpentine. The value obtained by deducting the acid-soluble MgO from the total MgO agreed with that required by the serpentine. The water not required by the serpentine was calculated to stichtite, and the remaining Cr_2O_3 to chromite. After deducting the iron of the stichtite and chromite from the total iron, 4·91 % Fe_2O_3 remained. This leads to the following mineral composition of the sample analysed: stichtite 45·97, serpentine 19·63, chromite 27·89, iron oxides 4·91 %.

In view of the large amount of associated minerals present in the sample, tests were carried out as a check on the mineral composition. In a series of extractions of the original powder, the strength of acid used was gradually increased, but the amount of iron dissolved remained practically constant, e.g. hot 1 : 1 H_2SO_4 dissolved only 1·90 % Fe_2O_3. This wide gap between complete solution of the stichtite iron and commencement of solution of the remainder of the

iron justifies the identification of the 4·91 % Fe_2O_3 with the iron oxides detected in the optical examination. No alumina was found in the acid extract.

There remained the rather remote possibility of the extraction of some finely divided serpentine by the cold acid. When the acid used was so weak as to exclude the possibility of attack of the serpentine, the ratios of $MgO : Fe_2O_3 : Cr_2O_3$ extracted (16·57 : 1·60 : 7·49 %), remained unaltered, although in this case solution of the stichtite was not quite complete. Moreover, no silica was detected in the *N*-acid extract.

The calculation of the percentage composition of the stichtite component leads to the formula $(Cr,Fe)_2O_3.7MgO.CO_2.13H_2O$, in which $Cr_2O_3 : Fe_2O_3$ is very nearly 5 : 1 (columns 2 and 3, p. 313).

There has been considerable divergence of opinion as to the composition of stichtite. This seems to be mainly due to the great difficulty of procuring pure material for analysis, to confusion as to the function of the ferric and chromium oxides, and as to the ratio of the magnesia to the sesquioxides. Petterd (analysis 4) proposed the formula $(Cr,Fe)_2O_3.6MgO.CO_2.13H_2O$, although the actual molecular ratio $MgO : R_2O_3$ calculated from his figures is 6·77 : 1. Hezner considered the SiO_2 and FeO in analysis 5 to be due to serpentine and chromite respectively, which were shown to be present by optical examination. On recalculating the figures on this basis, she found they agreed well with the formula $Cr_2O_3.7MgO.2CO_2.12H_2O$. Another analysis (6) of stichtite was carried out by Foshag, who assigned the mineral to the hydrotalcite group, including Al_2O_3 with the sesquioxides, and proposing the formula $R_2O_3.6MgO.CO_2.12H_2O$. His analysis, however, shows an appreciable quantity of unallotted SiO_2, although the Tasmanian material he used is described as containing serpentine. Finally, Hall (analysis 7) concluded that it was doubtful whether stichtite had a constant chemical composition.

All accounts of the mineral agree that stichtite occurs intimately admixed with serpentine and chromite ; siliceous minerals other than serpentine have apparently not been reported. It is reasonable to assume, therefore, that the bulk of the silica and the small quantities of ferrous iron reported in these analyses are present in the form of these minerals. When the analytical figures are recalculated on this basis (p. 315) it is seen that :

(1) The ferric and chromium oxides are mutually replaceable over a wide range (0–60 % Fe_2O_3).

(2) The molecular ratio $MgO : R_2O_3$ approximates very closely to seven in all cases.

(3) There are two equivalents of CO_2 in the molecule when Cr_2O_3 is the only sesquioxide present; when Cr_2O_3 is partially replaced by Fe_2O_3, the amount of CO_2 approximates to one equivalent, but is somewhat in excess of this amount in all cases.

(4) In three cases the sum of equivalents of CO_2 and H_2O is very nearly fourteen, suggesting that these components are to some extent interchangeable. Unfortunately, in the cases of Analyses 4 and 6 the temperature of expulsion of the water is not stated, and the figures given may include uncombined water.

Analyses of stichtite after deducting serpentine and chromite.

		Percentages.	Molecular Proportions.			Percentage Ratio $Cr_2O_3 : Fe_2O_3$.
Analysis 1.	Cr_2O_3 ...	8·16	0·054 } 0·064			84 : 16
	Fe_2O_3 ...	1·61	0·010 }			
	MgO ...	18·15	0·450	7·00		
	CO_2 ...	3·14	0·071	1·11 } 13·96		
	H_2O ...	14·91	0·826	12·85 }		
Analysis 4.	Cr_2O_3 ...	11·5	0·076 } 0·132	1·03		57 : 43
	Fe_2O_3 ...	9·0	0·056 }			
	MgO ...	36·0	0·893	7·00		
	CO_2 ...	7·2	0·164	1·28		
	H_2O ...	36·1	2·005	15·70 *		
Analysis 5.	Cr_2O_3 ...	18·11	0·119 0·119	1·01		100 : 0
	Fe_2O_3 ...	—	—	—		
	MgO ...	33·22	0·824	7·00		
	CO_2 ...	10·45	0·238	2·02 } 13·88		
	H_2O ...	25·15	1·396	11·86 }		
Analysis 6.	Cr_2O_3 ...	13·49	0·089 } 0·114	0·93		78 : 22
	Fe_2O_3 ...	4·04	0·025 }			
	MgO ...	34·49	0·855	7·00		
	CO_2 ...	6·94	0·158	1·29		
	H_2O ...	32·38	1·798	14·72 *		
Analysis 7.	Cr_2O_3 ...	7·10	0·047 } 0·113	0·99		41 : 59
	Fe_2O_3 ...	10·60	0·066 }			
	MgO ...	32·17	0·798	7·00		
	CO_2 ...	6·90	0·157	1·37 } 13·77		
	H_2O ...	25·45	1·413	12·40 }		

* Temperature at which H_2O is expelled not stated.

On this interpretation, all five analyses agree well with the following general formula for stichtite:

$$2(Cr,Fe)(OH)_3.5Mg(OH)_2.MgCO_3.Mg[CO_3,(OH)_2].4H_2O.$$

The chromium may be regarded as completely replaceable by iron, although in the analyses examined this replacement scarcely

exceeds 50 % in extent. There may be structural difficulties in the way of admitting complete replaceability of the carbonate radical by hydroxide over an indefinite range, and an examination of the analytical results does not exclude the possibility of replacement limited to definite stoicheiometric stages.

All descriptions show agreement as to the mode of occurrence of the mineral, small fragments of chromite serving as nuclei to masses of stichtite in the serpentine. In all but one of the reported occurrences, chromium occupies the larger part of the sesquioxide component ; in Hezner's sample, which represents the end-member of the stichtite series, the total absence of iron is accompanied by the entry of a second molecule of carbon dioxide in place of the equivalent of hydroxide. It is noteworthy that the associated serpentine in this case is free from ferric iron, whilst the serpentines accompanying the iron-bearing stichtites from Shetland and South Africa are distinctly ferruginous.

On quartz-kyanite-rocks in Unst, Shetland Islands, and their bearing on metamorphic differentiation.

By H. H. Read, D.Sc.
Professor of Geology, University of Liverpool.

[Read November 1, 1932.]

AMONG the many beautiful rocks of Unst, the most northerly of the Shetlands, is one composed of rosettes of pale blue kyanite set in a base of glassy quartz. This rock was mentioned by Heddle,[1] but has never been described, nor have its genetic relationships been considered. During the mapping of Unst for the Geological Survey, opportunity was afforded of examining the field-relations of these quartz-kyanite-rocks and of collecting adequate material for study. I am indebted to Sir John Flett, F.R.S., Director of the Survey, for permission to present this account. These rocks have a considerable intrinsic interest; in addition, their investigation is closely concerned with certain general problems in metamorphism, especially those connected with metamorphic differentiation. The present paper is therefore divided into two portions, the first dealing with the description and origin of the Unst rocks, and the second with more general aspects.

I. *Quartz-kyanite-rocks of Unst.*

The Country-rocks.—The north-eastern part of Unst is composed of chloritoid-kyanite-schists. These form the hills of Housi Field, Sothers Fields, Ward of Norwick, and Saxa Vord; from the last, the highest hill in the island, they take their name.[2] The Saxa Vord Group is well exposed in sea-cliffs which, though often hundreds of feet high, are for the most part readily accessible, and inland exposures are fairly numerous. The lithological composition and variations of the group are therefore quite well known, a circumstance of importance in what follows.

[1] M. F. Heddle, The county geognosy and mineralogy of Scotland. Min. Mag., 1879, vol. 2, p. 19; and The mineralogy of Scotland, 1901, vol. 2, p. 60.

[2] Summ. Prog. Geol. Surv. Great Britain for 1930, 1931, part 1, pp. 65, 66, 68.

By far the dominant rock-type is a greenish-grey schist. In slice (fig. 1) these schists, as developed on Saxa Vord itself, are found to be composed of kyanite, chloritoid, muscovite, quartz, and iron-ore, with chlorite in some examples and relics of staurolite and garnet in most. Kyanite builds prismatic crystals; swarms of small crystals are often seen in knots of micaceous material. Chloritoid occurs as

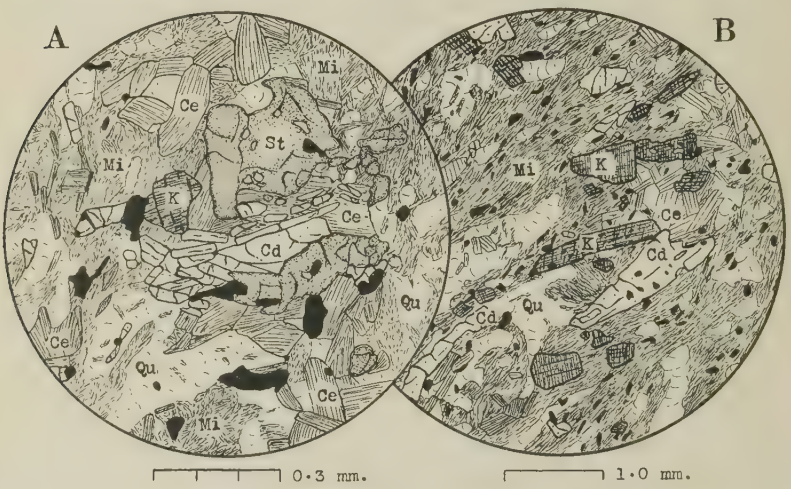

Fig. 1. Argillaceous rocks of the Saxa Vord Group.
A. Summit of Saxa Vord. B. Ritten Hamar, North Coast, Unst.
Cd = chloritoid, Ce = chlorite, K = kyanite, Mi = muscovite,
Qu = quartz, St = staurolite, solid black = iron-ore.

unoriented laths of normal characters. The ground-web consists of quartz grains and tiny colourless mica plates, these latter giving the schistosity directions. Iron-ore occurs as large subhedral grains. Staurolite forms irregular porphyroblasts sieved with quartz and ore pellets; with it chloritoid and rarely kyanite are associated in a fashion suggesting that they have arisen by destruction of the staurolite. Garnet is rare in the slices of these argillaceous schists, but in certain more quartzose types it is fairly common in spongy masses passing over into chlorite. Chlorite is absent in many of the chloritoid-kyanite-schists, but in certain examples it is abundant, appearing then to replace the chloritoid; such chloritic rocks show a lenticular sheared structure. It is suggested, therefore, that the metamorphic history of the Saxa Vord Group is complex; a development of staurolite and garnet has been followed by a phase of de-

struction of these minerals to give a chloritoid-kyanite assemblage and this is followed by conditions causing the formation of chlorite from the chloritoid.

The Quartz-kyanite-rocks.—The quartz-kyanite-rocks that are the subject of this paper occur as vein-like bodies in the kyanite-chloritoid-schist. Such veins may be observed at several localities, as, for example, in the Dale Burn where it is crossed by the road to the gun emplacement on Saxa Vord, in the saddle between Sothers Fields and Ward of Norwick, and in the upper part of the Burn of Skaw. Most of these veins are seen to lie along the schistosity planes, but transgressive veins have been noted. The veins observed in place have a maximum width of a foot or so, but blocks of exactly similar material reach an enormous size; some are estimated to contain at least thirty cubic yards. Hundreds of these blocks are scattered over the eastern slopes of Housi Field and Sothers Fields, the more prominent receiving names, such as the White Stane of Housi Field, the White Haggle, and so on. The quartz-kyanite-rocks thus form vein-like masses, often exceeding several yards in thickness, in the Saxa Vord kyanite-chloritoid-schists.

Two main varieties of these masses may be distinguished. In the first type, they are simple, uniform in composition, and vein-like. In the second, they form complexes with the country-rock, this occurring as flakes or irregular masses enclosed within the quartz-kyanite-rocks. At the margins of these irregular bodies, the country-rock is intimately mixed with patches of quartz-kyanite-rock. No hard and fast line can be drawn between the two types of masses and no genetic significance can be attached to this distinction.

The components of these rocks are quartz as almost glassy grains of large size, and kyanite as rosettes of pale blue crystals that reach a maximum length of two inches. Under the microscope the quartz grains are seen to have somewhat sutured margins and often show undulose extinction. In crushed fragments the kyanite exhibits normal characters. A few small flakes of muscovite are found in some specimens.

The arrangement of the kyanite in the masses and the positions of the country-rock cheeks and flakes are shown in figs. 2 and 3. The kyanite rosettes are confined to the margins of the veins or are based upon included pieces of country-rock.

Rocks immediately associated with the Quartz-kyanite-rocks.—The rocks intimately associated with the quartz-kyanite-rocks either as

included flakes, selvages to the veins, or as parts of the vein-complexes differ from the normal schist of the Saxa Vord Group in several particulars. They are coarser, much richer in kyanite, and usually wholly free from quartz (fig. 4). Their main component is kyanite; in some examples the rocks are entirely kyanite except for a few tiny patches of chlorite, sericite, and iron-ore. The kyanite here forms large interlaced or subradiate blades between which occur

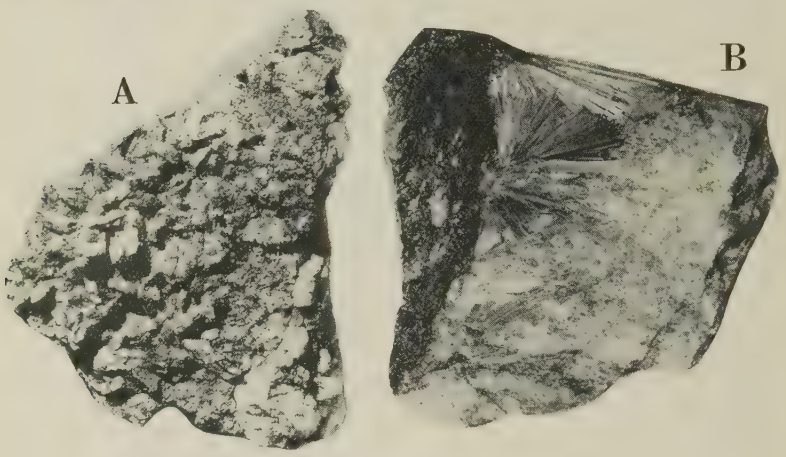

Fig. 2. Quartz-kyanite-rocks, Unst.

A. Kyanite crystals, average length ½ inch, on the selvage to a quartz mass seen at lower right-hand corner.

B. Kyanite rosettes, greatest length 1¼ inch, projecting into quartz (on right), and based upon quartz-free country-rock (on left).

the subordinate components. A common type of rock associated with the quartz-kyanite-rocks is formed of large blades of kyanite set in a base of large chlorite sheaves, or of tiny ripidolitic chlorite. Allied to these are rocks in which is present in addition a small amount of muscovite as flakes. Chloritoid enters into some of these rocks but is always subordinate in amount to the kyanite. Black iron-ore is abundant in most examples, most often as clots or veins in the chlorite; more rarely it forms grains enclosed within the kyanite. Quartz is usually absent; in a few examples it forms patches of grains into which project kyanite blades, such patches forming, in effect, minute quartz-kyanite-rocks.

The difference in mineral composition between the normal country-rock and that associated with the quartz-kyanite-rocks is brought

out by the results of micrometric measurements of typical rocks of both groups given in the table (p. 322).

In estimating the silica and alumina percentages of these rocks, the compositions of the minerals present have been somewhat arbitrarily chosen as follows: —for kyanite and muscovite, the theoretical

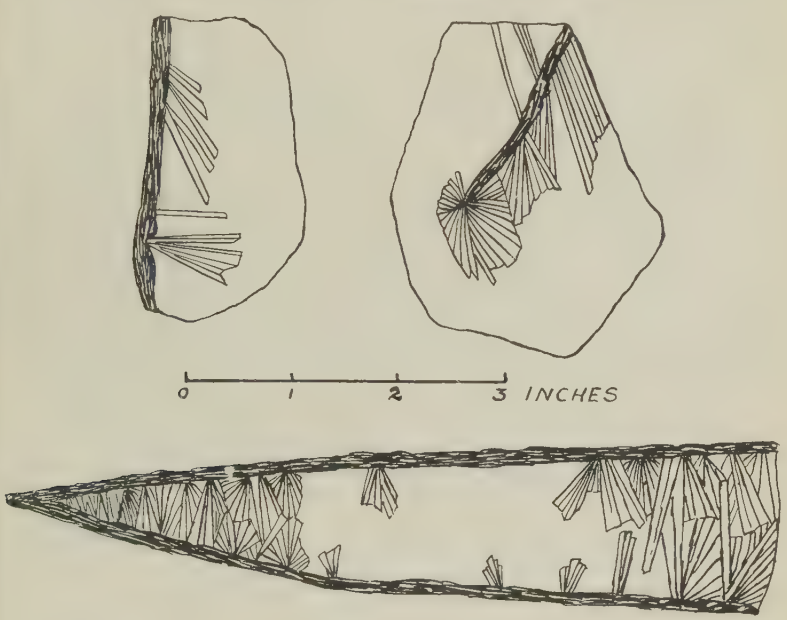

Fig. 3. Diagrammatic representation of the quartz-kyanite-rocks, showing kyanite rosettes, projecting into quartz, and based on selvages and flakes of quartz-free country-rock.

compositions; for chloritoid, Heddle's analysis[1] of the Vannlip Hillswick, Shetland, material; for staurolite, Rammelsberg's analysis[2] of St. Gotthard material; and for chlorite, von Hamm's analysis[3] of Zermatt material.

These estimates of silica and alumina can therefore be only approximately correct, but it is considered that the agreement among each group is sufficiently good to justify the view that the average

[1] M. F. Heddle, The mineralogy of Scotland, 1901, vol. 2, p. 123; and C. Hintze, Handbuch der Mineralogie, Leipzig, 1897, &c., Bd. 2, analysis XX, p. 677.

[2] C. Hintze, loc. cit., analysis VIII, p. 429.

[3] C. Hintze, loc. cit., analysis XLVI, p. 729.

figures give the correct order of the differences between the two groups. An analysis of a chloritoid-staurolite-schist from the summit of Saxa Vord, made by Mr. B. E. Dixon of H. M. Geological Survey, in connexion with the present writer's Survey work in Unst, shows silica 50·88 % and alumina 31·89 %. The differences between these figures and the average values for the Saxa Vord rocks given in the table below are most likely due to the arbitrary selection of the compositions of the minerals employed in the calculations, and to the difficulty of estimating correctly the quartz in the fine quartz-muscovite aggregate. It is of course possible that the compositions of the phases in the two groups are different, but such a variation cannot be sufficient to invalidate the general conclusion that the rocks intimately associated with the quartz-kyanite-rocks are much poorer in silica and richer in alumina than the normal argillaceous country-rocks of the Saxa Vord Group. These differences are held, as immediately explained, to be of genetic significance.

	Quartz.	Kyanite.	Chloritoid.	Chlorite.	Staurolite.	Muscovite.	Iron-ore.	SiO_2.	Al_2O_3.
Argillaceous rocks of the Saxa Vord Group.	17·0	1·9	9·4	18·4	15·3	30·7	7·3	44·6	27·2
	16·4	11·0	8·1	9·3	—	47·8	7·7	47·2	29·8
	13·7	2·8	5·6	—	6·2	65·6	6·1	47·6	32·6
	12·5	8·2	1·8	2·5	4·2	67·4	3·4	48·3	34·2
	11·2	5·6	5·2	1·9	—	73·6	2·5	48·5	34·2
							Average	47·2	31·6
Rocks associated with the quartz-kyanite-rocks.	—	73·1	—	20·5	—	—	6·4	34·0	48·6
	—	77·0	—	15·1	—	—	7·9	33·6	50·4
	—	66·5	10·7	—	—	—	22·8	27·2	46·3
	—	44·4	25·4	—	—	28·0	2·1	35·2	49·3
	—	72·6	—	9·3	—	18·1	—	38·1	54·0
	—	69·9	—	5·3	—	23·2	1·5	38·2	53·6
							Average	34·4	50·3

Origin of the Quartz-kyanite-rocks.—In many localities the quartz-kyanite-rocks have a habit like that of true veins. Their origin from igneous or external sources may be considered. It may be suggested that they are quartz veins of igneous origin that have either brought the components of kyanite in with them, or have taken up kyanite material from the vein walls. The habit of the kyanite shows that this mineral is not xenocrystic in the surrounding quartz, and it must be admitted that the quartz and kyanite are of con-

temporaneous formation. The known conditions of formation of kyanite in nature render it extremely unlikely that any solution such as an introduced magmatic entity was ever in existence, for it is difficult to conceive the action of stress upon introduced fluid bodies of the requisite size. Further, minerals of known end-stage pyrogenic origin, other than quartz, are absent from the quartz-

FIG. 4. Alumina-rich rocks intimately associated with the Unst quartz-kyanite-rocks. Housi Field, Unst.
Cd = chloritoid, Ce = chlorite, K = kyanite, Mi = muscovite, solid black = iron-ore.

kyanite masses, and no evidence of igneous activity is forthcoming from this area of the Saxa Vord Group. It is concluded, therefore, that these quartz-kyanite veins are not of igneous origin, a conclusion which is greatly strengthened by certain general considerations given later.

The second origin that may be suggested is that these quartz-kyanite-rocks and the associated alumina-rich selvages have original sedimentary compositions which have been unaltered during metamorphism. Against this view may be urged the habit of the quartz-kyanite-rocks, their complexes with the associated rocks, and the abnormal composition of the assemblage considered as sediments.

The origin of these rocks advanced by the writer is a metamorphic one, namely, that they have been formed by a process of endogenous secretion during the period of metamorphism. That this is the most

reasonable interpretation is indicated by a comparison of the normal argillaceous member of the Saxa Vord Group and the rocks intimately associated with the quartz-kyanite-rocks. We find the remarkable fact that the country-rock immediately adjacent to the quartz-kyanite-rocks is much richer in alumina than the normal country-rock of the district, or, put another way, shows an impoverishment in silica. The material of the quartz-kyanite veins represents the difference in composition between the normal country-rock and that associated with the veins.

The process considered to have operated is somewhat as follows. The fairly homogeneous country-rocks on being metamorphosed were converted into the usual quartz-bearing schists of the Saxa Vord Group. In certain localities, however, there took place concentrations of silica which had been excreted from the surrounding rocks, leaving these poorer in silica. Thus quartz bodies were formed in quartz-poor rocks. This separation is not quite clean, for from the silica-poor cheeks of the quartz masses and from the included flakes of silica-poor rocks, there were formed *pari passu* with the quartz those large rosettes of kyanite which render these rocks so striking. That there was ever in existence a body of quartz-kyanite 'magma' comparable in size with the quartz-kyanite-rocks as now found is extremely unlikely; these rocks grew by the gradual addition of quartz to already deposited quartz, so that only a small amount of solvent was in action at any one time. This solvent was most likely water which may well have been derived from the rock undergoing metamorphism.

It is concluded, therefore, that these quartz-kyanite-rocks were formed by a process of endogenous secretion during metamorphism, and that their complementary portion is indicated by the silica-poor country-rock immediately adjacent to them.

II. *Some General Remarks on Metamorphic Differentiation.*

Opinion on the possibility and scope of movement of material during metamorphism is extremely varied. On the one hand, there is the view that such movements are small and special. Harker[1] says 'Diffusion of dissolved material . . . is . . . restricted within very narrow limits' and again, 'phenomena indicative of segregation,

[1] A. Harker, Presidential address, Quart. Journ. Geol. Soc. London, 1919, vol. 74, p. lxx.

such as garnet-lenticles and streaks of quartz sillimanitisé, are found only in the highest temperature-grade of metamorphism '. At the other extreme stands Holmquist,[1] who would interpret migmatitic and vein-complexes as due to endogenous segregation during regional metamorphism ; the presence of an igneous rock here merely intensifies the process.

In his account of the metamorphic rocks of Adelie Land, F. L. Stillwell [2] had given in 1918 a general discussion of movement of material in metamorphism, and introduced the term ' metamorphic differentiation ' to denote the migration and segregation of material under metamorphic conditions. Stillwell laid great importance on solid diffusion as a process in metamorphism, the action of solvents being, in his opinion, only of minor account. Few petrologists familiar with metamorphic rocks would, I believe, agree with this view. P. Eskola [3] has recently discussed the principles of metamorphic differentiation, and has advanced a classification of metamorphic changes of composition. This classification is as follows :—

(1) Differentiation within a rock mass, due to
  (*a*) the growth of crystals or aggregates of crystals (the concretion principle),
  (*b*) the concentration of the least soluble substances (the principle of enrichment in the stablest constituents), or
  (*c*) the extraction and redeposition of the most soluble substances (the solution principle).

(2) Transfer of substances into and from a rock mass, effecting
  (*a*) addition,
  (*b*) metasomatism, or
  (*c*) extraction of substances.

The Unst rocks just described illustrate very clearly class 1 of Eskola's classification.

It is the purpose of the present writer now to discuss one aspect of metamorphic differentiation, that concerned with the development of quartz masses in metamorphosed argillaceous rocks. The occurrence of innumerable stringers, irregular stripes and even vein-like bodies of quartz in pelitic rocks is familiar to everyone who has

[1] P. J. Holmquist, Typen und Nomenklatur der Adergesteine. Geol. För. Förh. Stockholm, 1921, vol. 43, p. 612.

[2] F. L. Stillwell, The metamorphic rocks of Adelie Land. Australian Antarctic Expedition, 1918, vol. 3, pt. 1, pp. 12, 62, 200.

[3] P. Eskola, On the principles of metamorphic differentiation. Compt. Rend. Soc. Géol. Finlande, 1932, no. 5, p. 68 ; Bull. Comm. Géol. Finlande, 1932, no. 97, p. 68.

dealt with the rocks of metamorphic regions. The pelitic rocks of the Dalradian Highlands of Scotland, for example, such as the garnetiferous mica-schist of Perthshire, the Cowhythe gneiss of Banffshire and many others, are filled with such quartz masses. What is in the writer's opinion a very good example of the secretion of quartz on metamorphism is seen on the shore of Lake Nasijarvi, near Tammerfors in Finland; the Bottnian pelitic sediments show a development of quartz strings as soon as they attain even a low grade of metamorphism; it seems more reasonable to regard these quartz masses as excreted from the phyllites than as of igneous origin. Edward Greenly's great 'Geology of Anglesey' (1919) contains many references to venous quartz in the schists of that island. Greenly sees no reason to believe that the quartz material was introduced from without, but regards it as a product of the metamorphism (op. cit., p. 69). Since in such veins the quartz is always in excess over any other mineral, he points out that the country-rock must have been more siliceous, taken as a whole, than it is to-day (op. cit., p. 48). Here is a very clear recognition of the main principles of metamorphic differentiation.

On account of this excretion of quartz on metamorphism, it follows that analyses of pelitic schists containing quartz stringers do not represent the compositions of the original sediments from which such rocks are derived, but give too low a proportion of silica. The rocks from Unst described in this paper furnish an extreme case of this impoverishment in silica with the production of rocks rich in alumina. The possibility of the operation of metamorphic differentiation of this kind must be kept in mind in the making of averages of the composition of pelitic schists, in comparing analyses of such rocks, and in the use of specific analyses of pelitic country-rocks for the discussion of such matters as transfer in injection-complexes and at cross-cutting or xenolithic contacts.

A short and incomplete survey of the accounts of quartz-veining in metamorphic rocks shows very clearly the correspondence between the mineral content of the quartz veins and that of the country-rocks, and supplies additional examples of marginal enrichment in certain components. This correspondence indicates that such quartz-veinings belong to the metamorphic epoch, and to my mind illustrate the principles of metamorphic differentiation. The examples now given are arranged in some kind of order of increasing grade of the country-rocks.

Hans Breddin[1] has described quartz veins occurring in the lowly-metamorphosed sediments of the Middle Rhine which contain the minerals of the country-rocks and no others; chlorite is found in chlorite-bearing rocks, calcite in carbonate-bearing rocks. The veins are confined to sheared belts and especially to areas of argillaceous rocks. In the chlorite-sericite-phyllites of the Muness group of Unst there are found very large and abundant quartz veins; these veins often show large chlorites at their margins.[2] In the Anglesey schists, E. Greenly[3] has noted the formation of quartz lenticles containing the minerals of the country-rocks, such as chlorite, albite, or carbonates, at many localities. Holmquist[4] has grouped such veins as these as low-temperature phenomena and holds that at higher temperatures there arise the quartz-felspar veins of the veined gneisses or injection-complexes.

Eskola[5] has described and figured an example of the concentration of staurolite at the margins of quartz veins in mica-schist from Karelia. This case seems exactly similar to the Unst kyanite concentration, and I would suggest that the process of formation is the same, namely, an impoverishment of the marginal zone in silica, rather than a migration of staurolite or kyanite components through the rock.

The occurrence of the aluminium silicates in veins or masses of quartz is instructive. In the Correen Hills, Aberdeenshire, Heddle[6] records andalusite 'in the flagstone quarries of the Correen Hills, rarely, in pink and grey crystals in the quartz veins which cut the slate, and associated with mica. . . . Commonly in greyish-blue crystals dispersed throughout the slate'. The country-rock of the district is the andalusite-schist that covers so great an area in north-east Scotland. With regard to kyanite there are the Unst occurrences described in this paper. To these may be added various

[1] H. Breddin, Die Milchquarzgänge des rheinischen Schiefergebirges, eine Nebenerscheinung der Druckschieferung. Geol. Rund., 1930, vol. 21, pp. 367–388.

[2] Summ. Prog. Geol. Surv. Great Britain for 1930, 1931, part 1, pp. 68–69.

[3] E. Greenly, The geology of Anglesey. Mem. Geol. Surv., 1919, vol. 1, pp. 46, 48, 68, 81.

[4] P. J. Holmquist, loc. cit., 1921, p. 627.

[5] P. Eskola, Conditions during the earliest geological times as indicated by the Archean rocks. Ann. Acad. Sci. Fennicae, Ser. A, 1932, vol. 36, no. 4, pp. 58–59.

[6] M. F. Heddle, The mineralogy of Scotland, 1901, vol. 2, p. 59.

records by Heddle[1] of kyanite-bearing quartz veins, nodules or 'concretions' in kyanite-bearing country-rocks. For sillimanite, the best examples are supplied by faserkiesel knots in sillimanite-gneisses. The present writer cannot support the view put forward by K. Hinterlechner[2] and L. Rüger[3] that faserkiesel nodules are metamorphosed clay-galls.

This brief survey shows the correspondence between the accessory minerals of the quartz veins and masses and those occurring in the country-rocks. Such a correspondence can hardly be accounted for if these quartz masses are unconnected with the metamorphic processes, which for the lower grades at least must be only very distantly related to igneous intrusion. The writer is not sufficiently well acquainted with the literature on ore-bearing quartz veins to be able from the data there assembled to test the views set out in this paper.

It seems likely, therefore, that some measure of metamorphic differentiation can take place in all grades of metamorphism. It is an interesting task for students of metamorphism to inquire into the scale of this differentiation, its modes of action, and especially into certain appearances of selectivity, both with regard to rocks and minerals, that are obvious in the field.

[1] M. F. Heddle, op. cit., pp. 61–62.

[2] K. Hinterlechner, Geologische Verhältnisse im Gebiete des Kartenblattes Deutschbrod. Jahrb. Geol. Reichsanst., Wien, 1907, vol. 57, p. 339.

[3] L. Rüger, Über 'Faserkieselknollen' (Sillimanitquarzite) aus den Biotitgneisen des Mt. Arbino (Tessin) und ihre Deutung als Gerölle. Centralbl. Min., Abt. B, 1931, pp. 488–492.

A new meteoric iron found near Kyancutta, South Australia.

By L. J. Spencer, M.A., Sc.D., F.R.S.
With a chemical analysis by M. H. Hey, B.A., B.Sc.
Mineral Department, British Museum of Natural History.

[Read November 1, 1932.]

THE local interest aroused by the discovery in 1931 of the meteorite craters near Henbury in Central Australia[1] has led to the finding of a new meteoric iron in South Australia. This is due to the energy and enthusiasm displayed by Mr. R. Bedford of the Kyancutta Museum. According to his letter dated August 23, 1932, the mass was found in June 1932 by a farmer, Mr. L. G. Gardiner, whilst cultivating a sandy paddock 28 miles ESE. of Kyancutta. It was turned up from just beneath the surface. He describes it as weighing 72 lb., and being 17 inches long and roughly triangular in section with a thickness of about 8 inches. The mass is weathered and one face shows four sharply cut hemispherical pits (fig. 2) averaging $1\frac{1}{4}$ inches in diameter and 1 inch in depth. The main mass is now in the Kyancutta Museum.

Kyancutta is in Le Hunte County in the Eyre Peninsula, and a spot 28 miles ESE. is at about 33° 19′ S., 136° 2′ E., just over the border in Buxton Co. The postal address of Mr. Gardiner's farm is Kyancutta, and Mr. Bedford suggests the name *Kyancutta* for this new meteorite.

A nice slice (B.M. 1932, 1564) of the iron weighing 370 grams, together with small fragments and filings (24 grams) for analysis, has been generously presented by the Kyancutta Museum for preservation in the British Museum collection of meteorites. It measures $13\frac{1}{2} \times 6\frac{1}{2}$ cm., with a thickness of 1 cm. The uncut surface at the edge of the slice shows broad and shallow concave areas characteristic of meteoric irons that have weathered while buried in the surface soil. Each concavity marks the area of solution of the iron by free sulphuric acid developed by the decomposition of an enclosed nodule of troilite. The hemispherical pits mentioned by Mr. Bedford are evidently cavities left by troilite. These concave surfaces on the

[1] A. R. Alderman, Min. Mag. 1932, vol. 23, p. 19.

edge of the slice have a thin coating of hard scale, which shows up as a narrow black border on the polished section (fig. 3). The larger sawn surface shows five small nodules or grains of troilite measuring 1 to 5 mm. across; but on the smaller surface none was detected. On both surfaces there are lines or gashes (fig. 3), which bear some resemblance to 'Reichenbach lamellae'. They are about 1 to 3 cm. in length with a thickness of $\frac{1}{2}$ mm. or less. Along these lines rusting of the iron had taken place, with the sweating out of minute brown drops, between the time the piece was sawn and

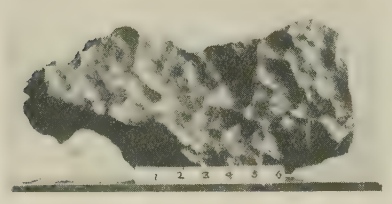

Fig. 1.

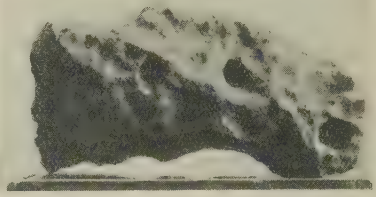

Fig. 2.

Meteoric iron of Kyancutta, South Australia.
Views of opposite sides. Scale of inches.

sent in August and when received in October. 'Reichenbach lamellae' are usually attributed to thin plates of troilite; but here there was no staining of the surface when the iron was treated with nitric acid. The tendency to rusting, with exudation of drops, along these lines is no doubt due to the presence of lawrencite. As seen on the polished and etched section, these lines are parallel to the bars of kamacite, and though most of them extend from the outer surface like cracks, some of them are entirely surrounded.

By smoothing and polishing the smaller of the two sawn surfaces the slice was reduced in weight to 350·4 grams. In working this iron it was found to be very hard—much harder than the Henbury iron, which it otherwise closely resembles; but it is readily malleable. A curious feature came out during the working of the iron. An approximately flat surface was first obtained by filing, and the surface was then ground on an iron plate with emery; but before the whole of the filed surface was levelled out the specimen was polished on a buff with magnesia powder. The filed surface then showed a smooth and brilliant polish; whilst the ground surface was still somewhat dull and it showed distinct indications of the lamellar

octahedral structure of the iron. On etching with very dilute nitric acid the lamellar octahedral structure was brought out prominently on the ground surface but less prominently on the filed surface. Further, the kamacite bands on the ground surface displayed a very marked oriented sheen when viewed at different angles with respect to the reflected light; whilst on the filed surface this was scarcely noticeable. Under the microscope the kamacite bands in the filed

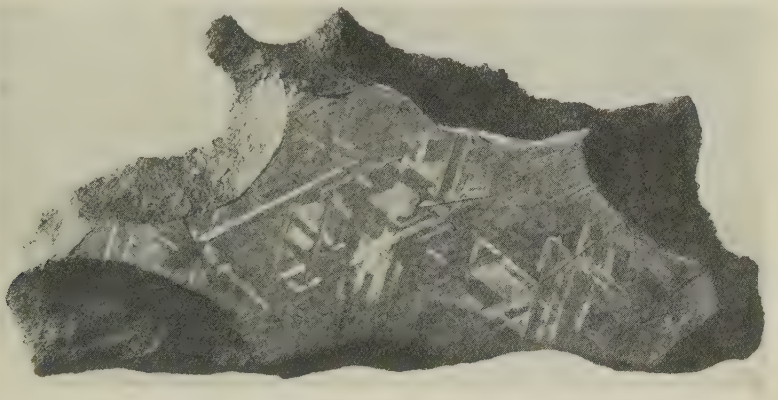

Fig. 3. Etched slice of the Kyancutta meteoric iron. $\times\frac{3}{4}$.

area show well-marked Neumann lines in several directions; but on the ground area these are scarcely perceptible. The structures to be seen in the microscopical examination of polished metal surfaces evidently depend largely on the method of preparing the surface. These differences are in part brought out in the photograph of the polished and etched surface (fig. 3). The section is approximately parallel to a face of the octahedron and the bands of kamacite shown in the etched figures ('Widmanstätten figures') have an average width of 1 mm., so that the iron is to be classed as a medium octahedrite. Very narrow bands of taenite are evident, and there are also the usual areas of plessite.

A digression on the term 'Widmanstätten figures' may not be here altogether out of place. As a form of terminology it seems scarcely necessary to describe the lamellar octahedral structure and the resulting etched figures common to all octahedral irons. It is, in any case, an awkward word the spelling of which is difficult to remember, while not a single one of the many spellings that have been given is correct! The following is a list of the many forms

that have been used, tracing back from the present time to the earliest use in 1813.

Widmanstätten figures (Encycl. Brit., 11th edit., 1911; Webster Dict., 1918).
Widmannstätten figures (Encycl. Brit., 9th edit., 1883; Encycl. Dict., 1902).
Widmanstättensche Figuren (Brockhaus Lex., 1903).
Widmanstätten'sche Figuren (Tschermak; Brezina; Cohen).
Widmannstättensche Figuren (Partsch, 1843; Handw. Naturwiss., 1915).
Widmanstætten (figures de) (S. Meunier, 1884).
Widmannstætten (figures de) (Larousse; S. Meunier, 1882, 1909).
Widmannstaettian figures (Encycl. Dict., 1902).
Widmannstaett's figures (Encycl. Dict., 1902).
Widmannstättian figures (Flight, 1887; Century Dict., 1899).
Widmannstätten's figures (Steenstrup, 1884).
Widmanstätt's figures (Steenstrup, 1877).
Widmanstädtsche Figuren (Chladni, 1819).
Widmannstädten'sche Figuren (Schweigger, 1813).

The first published mention of these etching figures was made in 1812 by K. A. Neumann,[1] who had developed them on sections of the Elbogen meteorite by etching with nitric acid. He states, on the information of E. F. F. Chladni, that the 'Streifen' (stripes) so produced had previously been obtained on the Agram (= Hraschina) meteorite by Herr von Widmanstädten (p. 207). In a note added by Chladni to this paper the name is spelt Widmannstädten (p. 204). The first definite application of this name to the figures was made in 1813 by J. S. C. Schweigger,[2] in an editorial note based on information supplied by Neumann; he gave the form Widmannstädten'sche Figuren. Later, in 1819, Chladni published a paper entitled 'Ueber die Widmanstädtschen Figuren',[3] which was said to be an extract from pp. 314–319 of his classical work 'Feuer-Meteore' (Wien, 1819). But in the latter, although there is mention of the 'Streifen' discovered by von Widmanstädten, the term Widmanstädtsche Figuren does not appear. C. von Schreibers (after whom schreibersite was named) in his 'Stein- und Metall-Massen' (Wien, 1820) also mentions the 'Streifen' discovered by von Widmanstätten (p. 1), but on p. 70 he spells the name von Widmannstätten. It was at Schreiber's request that von Widmanstätten (or Widmannstätten), Director of

[1] K. A. Neumann, Ann. Physik (Gilbert), 1812, vol. 42, p. 207; reprinted from [Hesperus, Prag, 1812, no. 55].

K. A. Neumann (1771–1866), Professor of Chemistry at Prag. Not J. G. Neumann after whom Neumann lines were named. Cf. Min. Mag., vol. 22, pp. 277–278.

[2] J. S. C. Schweigger, Journ. Chem. Physik (Schweigger), 1813, vol. 7, p. 174.

[3] E. F. F. Chladni, Journ. Chem. Physik (Schweigger), 1819, vol. 26, pp. 196–202.

the Royal Porcelain Works in Vienna, tried in 1808 the effect of heat on a slice of the Agram iron. He then found that the figures could be more easily developed by etching with nitric acid, and he afterwards etched several of the meteoric irons in the Vienna collection; but he himself published nothing on the subject.

As a matter of fact the name of the man who has been commemorated in this connexion for the past hundred and twenty years was not Widmanstätten, Widmannstätten, Widmanstädten, or Widmannstädten, as given by his contemporaries, but that of a noble family, Widmanstetter, of Graz in Styria. His full name and title were Alois Joseph Franz Xaver Beckh, Edler [Baron] von Widmanstetter. He was born at Graz on July 13, 1754, and died in Vienna on June 10, 1849.

But to return to the Kyancutta meteorite. The following are the results of a detailed chemical analysis (Fe : Ni : = 12·4) made by Mr. M. H. Hey, with the chlorine distillation method,[1] on the filings; and the specific gravity of 7·73(5) was determined by him by hydrostatic weighing of the slice of 350·4 grams.

Fe.	Ni.	Co.	Cu.	S.	P.	Cl.	C.	Insol.	Total.
90·57	7·30	0·39	trace	1·12	nil	trace	0·13	0·22	99·73

In chemical composition and in structure the Kyancutta iron shows a very close similarity to the Henbury iron.[2] Both are medium octahedrites containing about 7½% of nickel (Fe : Ni about 12 : 1). The locality of the new find lies about 620 miles south by east of Henbury, and the suggestion that this iron might be a transported mass of the abundant Henbury iron is not considered to be at all likely. Mr. Bedford with his knowledge and experience of the Henbury irons would have at once detected any attempt made to pass off a planted mass. Medium octahedrites with this percentage of nickel are in fact the most common type of meteoric iron. The iron from the meteorite craters discovered in 1932 at Wabar in the Arabian desert is of this type and so is the Piedade do Bagre from Brazil recently described in this Magazine,[3] and many others. The suggestion of transportation (which might perhaps apply in the case of the undue proportion of irons found in the United States of America) is therefore not entertained.

[1] M. H. Hey, Min. Mag., 1932, vol. 23, p. 13.

[2] A. R. Alderman, Rec. S. Austr. Mus., 1932, vol. 4, p. 555. [Min. Abstr., vol. 5, p. 159.]

[3] L. J. Spencer, Min. Mag., 1930, vol. 22, p. 271.

Meteoric stones from Suwahib, Arabia.

By W. Campbell Smith, M.C., T.D., M.A.
Deputy-Keeper in the Mineral Department
of the British Museum of Natural History.

[Read November 1, 1932.]

A METEORIC stone found in 1931 by Mr. Bertram Thomas at Buwah (lat. 20° 3′ 10″ N., long. 51° 25′ E.) in the region of Suwahib in the Rub' al Khali, Arabia, has already been described in this Magazine.[1] In 1932, Mr. H. St. J. B. Philby, travelling on a route some miles to the west of that followed by Mr. Bertram Thomas, picked up meteoric stones at three other places. Two of these are between 25 and 30 miles to the west of Buwah, and the third, Umm Tina, 3 miles north of Shanna, lies about 70 miles to the south.

Like the stone from Buwah, all the three new finds are heavily coated with limonite and are in a much decomposed condition. The alteration is farther advanced than in the Buwah stone, and the recognition of the specimens as fragments of meteorites is not easy.

A brief description of the specimens is given below:

(1) Three fragments found on February 10, 1932, at 'Ain Sala (lat. 19° 57′ 20″ N., long. 51° 2′ E.) 25 miles from Buwah. These pieces fit together, forming an ovoid stone bounded by nine surfaces, some of which are slightly convex, while the others are very slightly concave and almost flat. The weight of the three pieces together, including adhering sand grains, is 106·07 grams. Dimensions of the complete stone, $4 \times 3\frac{1}{2} \times 3\frac{1}{2}$ cm. A thin section shows the stone to consist of small and not very abundant chondrules in a matrix consisting partly of fragmental crystalline material and partly of limonite. The limonite occurs in minute patches, but also more abundantly in veinlets which traverse the whole stone. It is impossible to tell what proportion of the matrix originally consisted of nickel-iron or troilite. Only traces of these minerals can now be recognized, and it appears that their original amount was not very great.

[1] W. C. Smith, A new meteoric stone from Suwahib, Arabia. Min. Mag., 1932, vol. 23, pp. 43–50.

The chondrules include both eccentric radiating chondrules of enstatite and porphyritic chondrules consisting mainly of olivine.

(2) A single fragment found on February 12, 1932, at Adraj (lat. 20° 1′ N., long. 50° 56′ E.), 7½ miles approximately WNW. from 'Ain Sala and 32 miles almost due west of Buwah. This is an extremely irregular fragment, weighing 118·14 grams, with many rough faces, and measuring along three directions at right angles 6 × 5 × 3 cm. It is in a highly altered condition with deep cracks running inwards from the surface. A thin section shows it to consist of abundant very well-formed chondrules in a matrix permeated by limonitic veinlets and patches; many of the chondrules measure 1·5 mm. in diameter, but the average is near 0·4 mm. Both radiating eccentric enstatite chondrules and porphyritic and lamellated olivine chondrules are present. A polished surface examined with a vertical illuminator shows that the limonite completely masks any residual nickel-iron or troilite.

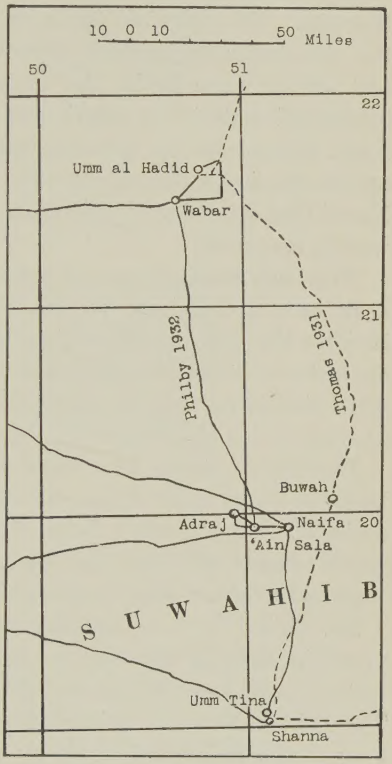

Fig. 1. Sketch-map showing localities of meteoric stones in the Rub' al Khali, Arabia.

Continuous line, Philby's route, 1932.
Broken line, Thomas's route, 1931.
Mr. Philby also collected meteoric iron at Wabar and Naifa.

Except for their more advanced stage of decomposition this specimen and the fragments from 'Ain Sala closely resemble the stone from Buwah, which was referred to Prior's Cronstad type (a bronzite-olivine-chondrite).

(3) About a dozen fragments collected on February 20, 1932, at Umm Tina (lat. 19° 1′ 40″ N., long. 51° 5′ E.), 3 miles north of Shanna well, and about 70 miles south of Buwah. The fragments

evidently represent a single specimen, possibly shattered by a blow. Total weight 70·2 grams. Specific gravity 2·98. Like the others it is heavily coated with limonite, which also permeates the whole stone. A thin section shows a rather confused mass of chondrules, mostly coarse, fibrous, some porphyritic, and all deeply stained with limonite. The spherical forms of chondrules are not very marked, the chondrules being close packed and very numerous. Enstatite and olivine seem to be the main constituents. The amount of interstitial material is small, and it does not seem probable that much nickel-iron was present originally, though there are small opaque patches scattered through the section. It thus resembles the Baroti type of Prior (hypersthene-olivine-chondrite). The stone is weakly magnetic.

With such poorly preserved material it is not easy to make identifications with certainty, but the characters of the specimens seem to indicate that the fragments from 'Ain Sala and Adraj are similar to the meteoric stone from Buwah and may belong to the same 'shower', while the meteoric stone from Umm Tina seems sufficiently different to suggest that it belongs to a separate fall.

That all the stones were found near wells may suggest that they have been carried by Arabs and dropped here and there at halts by accident. On the other hand, it may be urged that only at halts would stones like these be noticed. There may be many others scattered over the area in which these fragments were found.

Mr. Philby is to be congratulated on the collection of this unpromising looking material, so insignificant in comparison with his meteoric iron from Wabar and all the unique products of its impact. The British Museum is indebted for these specimens to H.M. the king of the Hejaz and Nejd, by whom they have been graciously presented.